FPGA IMPLEMENTATION FOR FAULT DETECTION ON A POWER TRANSMISSION LINES

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ABSTRACT

Transmission lines are designed to transfer electric power from source locations to distribution networks. However, their lengths are exposed to various faults. Protective relay and fault recorder systems, based on fundamental power frequency signals, are installed to isolate and the faulty line and provide the fault position. However, the error is high especially in transmission lines. In this study presents an approach to the problem of fault detection in transmission line by using FPGA. The idea is to use concepts from signal processing and wavelet theory using C++ code to create sensitive fault detection. The output signal of the speed deviations of generator are taken as the input for wavelet analysis. By using Quartus II software and Nios II software the C++ code run in FPGA (DE2) board where the "oscillation signatures" are recorded using Multi Resolution Analysis (MRA) Wavelet Transform. The MRA decomposes the signal where the components are analyzed in the FPGA for their energy content and characteristic and then used as a feature for different classes and locations of the fault. The output of FPGA is saved in mat file and also fed to the Probabilistic Neural Network (PNN) using Matlab M-file program to give the location and classification of the fault. Then, test the system by Adding noise to the data and run the PPN algorithm. The approach described in this study does not depend on the availability of an accurate mathematical model. Hence it is expected to be robust and of wide applicability. Therefore, this study will show that FPGA can be used to be a new approach to fault detection on power transmission lines.

ABSTRAK

Talian penghantar adalah direka untuk memindahkan tenaga elektrik daripada lokasi-lokasi sumber kepada rangkaian pembahagian. Bagaimanapun, panjang talian tersebut terdedah kepada pelbagai kecacatan. Sistem pelindung suis elektrik dan perakam kecacatan, berdasarkan asas isyarat frekuensi tenaga, adalah dipasang untuk memencilkan kecacatan talian dan menyediakan maklumat kedudukan kecacatan. Bagaimanapun, kesilapan masih tinggi terutama di dalam talian-talian penghantar. Kajian ini membentangkan satu pendekatan untuk masalah pengesanan kecacatan dalam talian penghantar dengan menggunakan FPGA. Gagasan kajian ini adalah bagi menggunakan konsep-konsep daripada asas pemprosesan isyarat dan teori *wavelet* menggunakan kod C++ untuk mewujudkan pengesanan kecacatan yang sensitif. Isyarat output daripada penyimpangan kelajuan penjana diambil sebagai input untuk analisis *wavelet*. Dengan menggunakan perisian Quartus II dan perisian Nios II kod C++ untuk menjalankan papan FPGA (DE2) di mana "*oscillation signatures*" direkodkan menggunakan *Multi Resolution Analysis* (MRA) *Wavelet Transform*. MRA menguraikan isyarat yang dianalisiskan dalam FPGA untuk kandungan tenaga dan ciri isyarat tersebut dan kemudiannya digunakan sebagai satu ciri untuk membezakan kelas-kelas dan lokasi-lokasi kerosakan. Output bagi FPGA disimpan di dalam fail *mat* dan juga dimasukkan kepada *Probabilistic Neural Network* (PNN) menggunakan program M-Fail Matlab untuk memberikan lokasi dan kelas kerosakan. Kemudian, sistem diuji dengan menambahkan gangguan kepada data dan menjalankan algoritma PPN. Pendekatan yang digambarkan dalam kajian ini tidak bergantung kepada satu model matematik yang tepat. Dengan jangkaan bahawa ia mempunyai pendekatan yang teguh dan memiliki kemampuan yang luas, kajian ini akan menunjukkan bahawa FPGA boleh digunakan sebagai satu pendekatan baru untuk pengesanan kecatatan pada talian-talian penghantaran kuasa.

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CHAPTER 1

INTRODUCTION

An electric power system comprises of generation, transmission and distribution of electric energy. Transmission lines are used to transmit electric power to distant large load centers. The rapid growth of electric power systems over the past few decades has resulted in the increase of large number of lines in operation and their total length. These lines are exposed to faults as a result of lightning, short circuits, faulty equipments, mis-operation, human errors, overload, and aging. Many electrical faults manifest in mechanical damages, which must be repaired before returning the line to service. The restoration can be expedited if the fault location is either known or can be estimated with a reasonable accuracy. Fault causes short and long term power outages for customers and may lead to significant losses especially for the manufacturing industry. Fast detecting, isolating, locating and repairing of these faults are critical in maintaining a reliable power system operation. When a fault occurs on a transmission line, the voltage at the point of fault suddenly reduces to a low value. This sudden change produces a high frequency electromagnetic impulse called the traveling wave (TW). These traveling waves propagate away from the fault in both directions at speeds close to that of light. To find the fault, the captured signal from instrument transformers has to be filtered and analyzed using different signal processing tools. Then, the filtered signal is used to detect and locate the fault. It is necessary to measure the value, polarity, phase, and time delay of the incoming wave to find the fault location accurately. [1]

An interconnected power system cannot operate without control. This is affected by a combination of manual operator controls and automatic control. The operators control the power that the generator supplies under normal operating conditions and the automatic controls come into play to make necessary fast adjustments so as to maintain the system voltage and frequency within design limits following sudden changes in the system. Thus, most generators have speed governing systems which automatically adjust the prime mover driving the generator so as to keep the generator speed constant, and voltage regulating systems which adjust the generators" excitation to maintain the generator voltages constant. The automatic controls in power systems must, as with other automatic feedback controls, be designed so that oscillations decay rather than grow.

The importance of power supply reliability is growing with the scale and complexity of electric power systems, and with the increasing use of communication devices and instruments. In modern ultra high voltage transmission networks, a faulty line is identified and reenergized within two or three cycles after a fault occurs. This may seem very fast, but a device must withstand the heavy over current that flows during this period, which requires large size and capacity. Thus, faster fault location would contribute to simpler and more efficient transmission equipment.

At present, lumped-parameter line models are used for fault detection and location in most cases. On the other hand, there are methods of fault location and detection based on surge waveforms generated by ground faults, such as using transient voltage/current waveforms, correlation, and others. Surge phenomena propagate in air at near-light speed; hence, a fault may be detected in an extremely short time compared to the system power period.

For the purpose of stable detection of such surge waveforms, the wavelet transform, a signal processing method that has recently gained popularity, was employed for fault location. In contrast to the Fourier transform, with the wavelet transform, a signal in the time domain is decomposed in the time and frequency spaces, and hence transient waveforms can be localized in terms of both time and frequency, and then analyzed. In addition, the wavelet transform allows the buildup starting point and other singular points of a waveform to be extracted.

1.1 Problem statement

Conventional fault detection algorithms are designed based on current or voltage magnitude measurements. Increase of current magnitude or decrease of voltage/impedance magnitude could be considered as a measure to detect a system fault. These algorithms are dependent on various factors such as fault resistance and power system short circuit capacity.

Current based starters get confused when load current is significant compared to fault current. Conventional over current based starters may not be able to detect faults with high amount of fault resistance.

For remote low current faults, no clear under voltage condition arises at the relay location. In the case of a close-in fault on a weak system, all voltages deviate from the nominal value. Therefore, the voltage based starters might not be able to perform correctly for different fault conditions. For the conventional based fault detectors, current and voltage magnitudes should be estimated correctly using appropriate filtering algorithms. When a fault happens on a transmission line, the power system goes through a transient period. It might not be easy to determine current/voltage signal magnitude fast and precisely during the transient period after the occurrence of the fault.

As power systems grow both in size and complexity, it becomes necessary to identify different system faults faster and more accurately using more powerful algorithms. It would be desirable to design a reliable and fast algorithm to classify different power system faults for various system parameters and fault states [2].

In this study, a hardware implementation of fault detection and location based system is proposed. A prototype system will be developed on an FPGA (Field Programmable Gate Array), which proves to be capable real-time fault detection.

1.2 Objective

The main objective for this project is to create a new approach of fast fault detection in power system. This research is the continuation of the previous study for fast fault detection in power transmission lines.

- To convert m-file Matlab algorithm to C++ code or rewrite C++ code for wavelet program, where the output signal of the speed deviations of the generator are taken as the input for wavelet analysis. The result of the analysis will be the features for different classes and location of the fault.

- To implement the algorithm in the FPGA board by using NIOS II and Quartus II software.

- To take the output of FPGA as input to neural network to give the location and classification of the fault.

1.3 Scope

The boundaries of studies for this project are analyzing signal and wavelet in C++ software using Multi Resolution Analysis (MRA) Wavelet Transform. The original fault signal from the generator will be analyzed and characteristics will be studied on FPGA board by using NIOS II and QUARTUS II software. Wavelet analysis is the breaking up of a signal into scaled versions of the original wavelet (mother wavelet) which is an oscillatory waveform of effectively limited duration that has average value of zero. By using artificial intelligence method, the signal will be classified and tested. The MATLAB algorithm has been produced, compiled and rewritten Visual as C++ code. The algorithm will be applied using NIOS II and QUARTUS II software to Altera DE2 board.

1.4 Thesis Outline

Chapter 1: Gives the brief introduction about the thesis. This chapter tells the objective and scope for continuing this research.

Chapter 2: Constitutes the introduction of fault detection on transmission lines using wavelet transforms and explains some of previous papers.

Chapter 3: This chapter consists of background of the project; shows the Basic concepts of previous study in detail, FPGA board, wavelet transform and Probabilistic Neural Networks (PNN).

Chapter 4: Consists of the methodology process by showing the detailed diagram of the project methodology and highlights briefly the steps that have been taken to meet the objective of this project.

Chapter 5: Presents the results of fault detection on transmission line using FPGA board, which applies three phase fault. The signals become the output from the generator and those having the best features become the input data to the db5 , FPGA is used to train it by using Probabilistic Neural Networks (PNN)

Chapter 6: Consists the conclusion and some discussion about the future works for this study.

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